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2020 Update: Stock Assessment of the Eastern Oyster, *Crassostrea virginica*, in the Maryland waters of Chesapeake Bay

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Maryland Department of Natural Resources Fishing and Boating Services

in consultation with

The University of Maryland Center for Environmental Science

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2020 Maryland Oyster Stock Assessment Update Summary

1 Introduction

The first Maryland oyster stock assessment was completed in December 2018. The stock assessment used a stage-structured model to estimate abundance and fishing rates as well as a model with linked shell and population dynamics to develop sustainable fishing reference points to guide fishery management (Maryland Department of Natural Resources, 2018). Stages used in the model are described in Section 2.1. The stage-structured model integrated several data sources including oyster buy ticket data, the Maryland Department of Natural Resources (DNR) fall dredge survey, oyster and shell planting data, bottom mapping data, and the Maryland patent tong survey. The results of the stage-structured model were used to estimate sustainable fishing mortality reference points. The objective of this document is to summarize an updated run of the 2018 Maryland Oyster Stock Assessment with data from the 2018-2019 and 2019-2020 seasons.

2 Materials and Methods

2.1 Model Description

The stage-structured model and the reference point estimation models were unchanged from the versions used in the 2018 stock assessment peer review (Maryland Department of Natural Resources, 2018). Stage-structured models were applied separately for each of 36 NOAA codes to estimate time series of abundance, harvest fraction (fishing levels), and natural mortality rates of oysters. The five stages used in the models are those described in the fall dredge survey: spat (recently settled oysters), small (≥ one year old and < 3 inches), market (≥ one year old and ≥ 3 inches), small box (shells of deceased oysters still connected at the hinge), and market box. The model year began October 1, which is the beginning of the oyster season for most gears. The beginning of the model year (October 1) is about the same time as the fall dredge survey. The modeled processes included recruitment (natural spat set and plantings), growth from small to market sizes, natural mortality (including disease-related mortality) of smalls and markets, the effect of fishing on small and market oysters (fishing levels), changes to habitat over time, effects of planting substrate and oysters, and the disarticulation of small and market boxes.

2.2 Reference Points

The target (U_{MSY}) and limit (U_{limit}) harvest fraction reference points were estimated using the model that was developed in the 2018 Maryland Oyster Stock Assessment (Maryland Department of Natural Resources, 2018). This model describes population growth as a logistic function of abundance with carrying capacity determined by the amount of habitat. The amount of habitat depends on habitat production from living oysters, habitat loss, and a maximum amount of potential oyster habitat in the system. Additionally, the model includes planted oysters and shell or other substrate. Several of the original parameters in the Wilberg et al. (2013) model were not estimable, so they were fixed at values from the literature as described in the 2018 Maryland Oyster Stock Assessment (Maryland Department of Natural Resources, 2018). Lastly,

the model required a parameter to convert from habitat in units of oysters to habitat in units of area. A discrete time version of the model was fitted with linked habitat dynamics to estimates of market-sized oyster abundance and area of habitat from the stage-structured assessment models for each NOAA code.

The lower limit abundance reference point was the lowest estimated abundance for the years 1999-2017. NOAA Codes would be considered "depleted" if abundance falls below the lower limit abundance reference point.

2.3 Data

The 2018 Maryland Oyster Stock Assessment was updated with the two most recent years of data: 2018-2019 harvest; 2019-2020 harvest; 2018 fall dredge survey; 2019 fall dredge survey; 2018 seed and shell plantings; and 2019 seed and shell plantings. These updated data include: (1) buy ticket harvest data, which are used to summarize fishing effects through the depletion analyses and used by the stage-structured model in the form of total harvest by season and NOAA Code; (2) Maryland fall dredge survey data, which are used as indices of abundance for live oysters, boxes, and estimated recent natural mortality; and (3) seed and shell planting data, which are used to account for plantings of hatchery-reared spat and addition of fresh and dredged oyster shell, clam shells, and alternate materials (e.g., rocks).

A mistake in the computer code used to calculate harvest within each NOAA Code was corrected. The previous code inadvertently excluded some buy ticket records (e.g., single patent tong, double patent tong, rake, and scrape), which caused an under count of harvest in some NOAA Codes for some years. Fixing the code did not qualitatively change the results for the assessment except for NOAA Codes 57 and 27. NOAA Code 27 is now estimated to be below the target harvest rate in the 2017-2018 season whereas for this same season it was estimated to be between the target and limit harvest rate in the 2018 Maryland Oyster Stock Assessment. NOAA Code 57 is now estimated to be between the target and limit harvest rate reference points in the 2017-2018 season whereas during this same season it was estimated to be above the upper limit harvest reference point in the 2018 Maryland Oyster Stock Assessment.

3 Results

3.1 Market Abundance

Maryland-wide, the estimated abundance of market oysters (three inches and larger) varied between 214 million and 684 million oysters (Fig. 1). Estimated market abundance was highest in 1999 at 684 million, the initial year of the time series, decreased to 214 million in 2003, and generally remained below 284 million until 2010. After 2010 abundance increased to the third highest value in the time series in 2014 (500 million) before declining and then increasing again in the final year to 453 million, the fifth highest in the time series. In 1999, estimated market abundance was highest in the Choptank River and Eastern Bay Regions, but after 2007 abundance was generally highest in the Choptank River and Tangier Regions. Abundance in the Choptank River and Tangier Sound regions in 2019 were the 2nd and 4th highest, respectively, of the time series.

3.2 Small Abundance

Maryland-wide, the estimated abundance of small oysters (older than one year, but less than three inches) varied between 247 million to 1,038 million oysters (Fig. 2). Estimated abundance of small oysters was highest in 2000, the second year of the time series, and then decreased to 224 million in 2002. After 2002 estimated small abundance fluctuated over time with no strong trend. Peaks occurred in 2003, 2007, 2011, 2013, and 2017 when estimated small abundance ranged from 456 million to 668 million. Estimated small abundance in the most recent year was 433 million, which is slightly below the long-term mean of 480 million. Estimated small abundance was relatively high (> 150 million) in the Choptank River, Tangier Sound, Eastern Bay, and Mainstem regions at the beginning of the time series, but after 2010 estimated small abundance was highest in the Choptank River and Tangier Sound regions.

3.3 Spat Abundance

Maryland-wide, the estimated abundance of spat varied between 128 million to 1,266 million oysters (Fig. 3). Estimated spat abundance was highest in 1999, the initial year of the time series, and decreased to 394 million in 2000. After 2000, estimated spat abundance fluctuated over time with no strong trend. After 1999, peaks occured in 2002, 2006, 2010, 2012, and 2016 when estimated spat abundance ranged from 582 million to 1007 million. Estimated spat abundance in the most recent year was the 6^{th} lowest in the time series. Estimated spat abundance was generally highest at the beginning of the time series in all regions, but only the Choptank River and Tangier Sound regions have consistently had relatively high (> 100 million) estimated spat abundance after 1999.

3.4 Total Abundance

Maryland-wide, estimated total abundance (spat, smalls, and markets combined) varied between 0.8 billion and 2.79 billion oysters (Fig. 4). Estimated abundance of all oysters was highest in 1999, the initial year of the time series, and decreased to 0.8 billion in 2005, which is the year with the lowest estimated total abundance in the time series. After 2005, estimated total abundance generally stayed around 1 billion oysters except for peaks in 2010 and 2012 when abundance reached 1.6 and 1.9 billion, respectively. Estimated total abundance in the most recent year was 1.2 billion, which is slightly below the long-term mean of 1.3 billion. Estimated total abundance was highest in 1999 for all regions except the Tangier Sound region. After 1999, estimated total abundance was generally below 200 million for the Mainstem, Severn/South Rivers, Patuxent/Potomac Rivers, and Eastern Bay regions. However, estimated total abundance for the Choptank River and Tangier Sound regions was above 200 million for almost all years in the time series.

3.5 Changes in Harvest Fraction and Market Abundance Since Last Assessment

In 75% of NOAA Codes the harvest fraction decreased between 2017 and 2019 (Table 1). In most NOAA Codes where the harvest fraction increased, it was negative (i.e., the estimated number of market oysters from plantings was higher than the number of market oysters harvested). NOAA Codes 137, 192, and 229 were the only NOAA Codes where harvest fraction was positive and increased from 2017 compared to 2019. Most (72%) NOAA codes experienced an increase in market abundance since 2017, the final year in the 2018 Maryland Oyster Stock

Assessment (Table 1). Market abundance decreased from 2017 to 2019 in NOAA Codes 5, 25, 60, 82, 99, 131, 174, 192, 331, and 337.

4 Reference Points and Stock Status

4.1 Overfishing

In the 2019-2020 fishing season, five NOAA Codes had harvest fractions above the upper limit reference point (U_{limit}), six were between the target and upper limit reference points, and 25 were at or below the target reference point (Fig. 5). The NOAA Codes above the limit reference point were 96, 137, 192, 292, and 537. The NOAA Codes between the target and threshold reference point were 43, 72, 78, 86, 168, and 229. Showing progress from the prior assessment, the number of NOAA Codes above the upper limit reference point declined from 18 in the last year of the 2018 Maryland Oyster Stock Assessment to 5 in the last year of the 2020 Maryland Oyster Stock Assessment Update, while the number of NOAA Codes at or below the target increased from 15 to 25 (Table 2).

4.2 Depleted

Estimated market abundance in three NOAA Codes (82, 131, and 331) was below the lower limit abundance reference point (Fig. 6). Estimated market abundance in NOAA Codes 131 and 331 was at the minimum value in the last year of the 2018 Maryland Oyster Stock Assessment and has declined since then. Maryland DNR biologists indicate the declines in these areas are due to environmental causes and not harvest since these areas include sanctuaries (69%, 98% and 100% of NOAA Codes 131, 082 and 331, respectively, are sanctuary areas) and were not estimated to be experiencing overfishing in the most recent two years.

References

Maryland Department of Natural Resources. 2018. A stock assessment of the eastern oyster, *Crassostrea virginica*, in the Maryland waters of Chesapeake Bay. Final Report November 2018. http://dnr.maryland.gov/fisheries/Pages/oysters/Oyster_Stock_Assess.aspx

Wilberg, M.J., Wiedenmann, John R., Robinson, J.M. 2013. Sustainable exploitation and management of autogenic ecosystem engineers: Application to oysters in Chesapeake Bay. Ecological Applications 23, 766–776.

Table 1. Comparison of estimated harvest fraction and market abundance within each NOAA Code between 2017 (the last year of the 2018 Maryland Oyster Assessment) and 2019 (the last year of the 2020 Maryland Oyster Assessment).

	Harvest Fraction			Market Abundance		
NOAA Code	2017	2019	Change	2017	2019	Change
5	0.05	0.02	down	0.44	0.32	down
25	-0.92	-0.75	up	16.43	15.61	down
27	0.03	-0.04	down	5.41	6.99	up
39	0.10	-0.27	down	20.67	24.86	up
43	0.57	0.44	down	2.95	11.06	up
47	0.20	0.13	down	2.47	4.92	up
53	-0.12	-0.69	down	29.83	82.09	up
57	0.17	0.03	down	2.66	3.22	up
60	0.03	-0.07	down	4.88	3.94	down
62	0.05	-0.13	down	19.13	19.41	up
72	0.44	0.16	down	2.79	2.90	up
78	0.87	0.34	down	4.72	6.69	up
82	-4.98	-1.55	up	2.57	1.56	down
86	0.52	0.21	down	0.52	0.60	up
88	-3.16	-3.11	up	1.53	1.53	up
96	0.25	0.07	down	0.99	1.32	up
99	0.01	0.00	down	0.92	0.60	down
127	-0.47	-1.19	down	13.69	14.85	up
129	0.42	0.11	down	2.00	3.50	up
131	-1.24	-1.71	down	4.91	2.96	down
137	0.50	0.52	up	2.92	5.92	up
168	0.19	0.10	down	4.98	13.75	up
174	0.09	0.00	down	0.06	0.04	down
192	0.28	0.32	up	5.40	5.14	down
229	0.04	0.09	up	5.35	11.20	up
231	-0.29	-0.63	down	6.24	9.33	up
237	-0.38	-0.28	up	10.19	13.89	up
268	0.16	-0.06	down	1.29	2.31	up
274	-0.20	-0.44	down	6.66	7.69	up
292	0.49	0.47	down	15.10	40.89	up
331	0.00	0.00	down	0.70	0.53	down
337	-1.59	-1.17	up	21.07	9.49	down
368	0.15	-0.59	down	2.43	4.51	up
437	-5.23	-2.36	up	24.10	34.51	up
537	0.33	0.22	down	22.49	39.75	up
637	-0.04	-2.31	down	14.91	45.30	up

Table 2. Estimated harvest fraction (adjusted for plantings) for market oysters during 2017-2019 in each NOAA Code relative to the upper limit (U_{limit}) and target (U_{msy}) harvest fraction reference points. Green shading indicates estimates at or below the target, amber indicates estimates above the target but equal to or below the threshold, and red indicates estimates above the threshold reference point. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

NOAA Code	Threshold	Target	2017	2018	2019
5	0.12	0.06	0.05	0.04	0.02
25	0.00	0.00	-0.92	-0.74	-0.75
27	0.15	0.07	0.03	-0.13	-0.04
39	0.04	0.02	0.10	-0.25	-0.27
43	0.55	0.28	0.57	0.20	0.44
47	0.32	0.16	0.20	0.08	0.13
53	0.06	0.03	-0.12	-0.58	-0.69
57	0.18	0.09	0.17	0.09	0.03
60	0.00	0.00	0.03	-0.05	-0.07
62	0.00	0.00	0.05	-0.07	-0.13
72	0.23	0.12	0.44	0.26	0.16
78	0.38	0.19	0.87	0.55	0.34
82	0.00	0.00	-4.98	-3.80	-1.55
86	0.23	0.11	0.52	0.36	0.21
88	0.00	0.00	-3.16	-2.73	-3.11
96	0.04	0.02	0.25	-0.16	0.07
99	0.00	0.00	0.01	0.00	0.00
127	0.00	0.00	-0.47	-0.85	-1.19
129	0.28	0.14	0.42	0.22	0.11
131	0.00	0.00	-1.24	-1.04	-1.71
137	0.26	0.13	0.50	0.51	0.52
168	0.16	0.08	0.19	-0.12	0.10
174	0.00	0.00	0.09	0.00	0.00
192	0.31	0.15	0.28	0.18	0.32
229	0.10	0.05	0.04	0.02	0.09
231	0.00	0.00	-0.29	-0.34	-0.63
237	0.00	0.00	-0.38	-0.19	-0.28
268	0.10	0.05	0.16	-0.12	-0.06
274	0.00	0.00	-0.20	-0.34	-0.44
292	0.41	0.21	0.49	0.20	0.47
331	0.00	0.00	0.00	0.00	0.00
337	0.00	0.00	-1.59	-1.34	-1.17
368	0.00	0.00	0.15	-0.62	-0.59
437	0.02	0.01	-5.23	-1.81	-2.36
537	0.22	0.11	0.33	0.26	0.22
637	0.02	0.01	-0.04	-1.05	-2.31

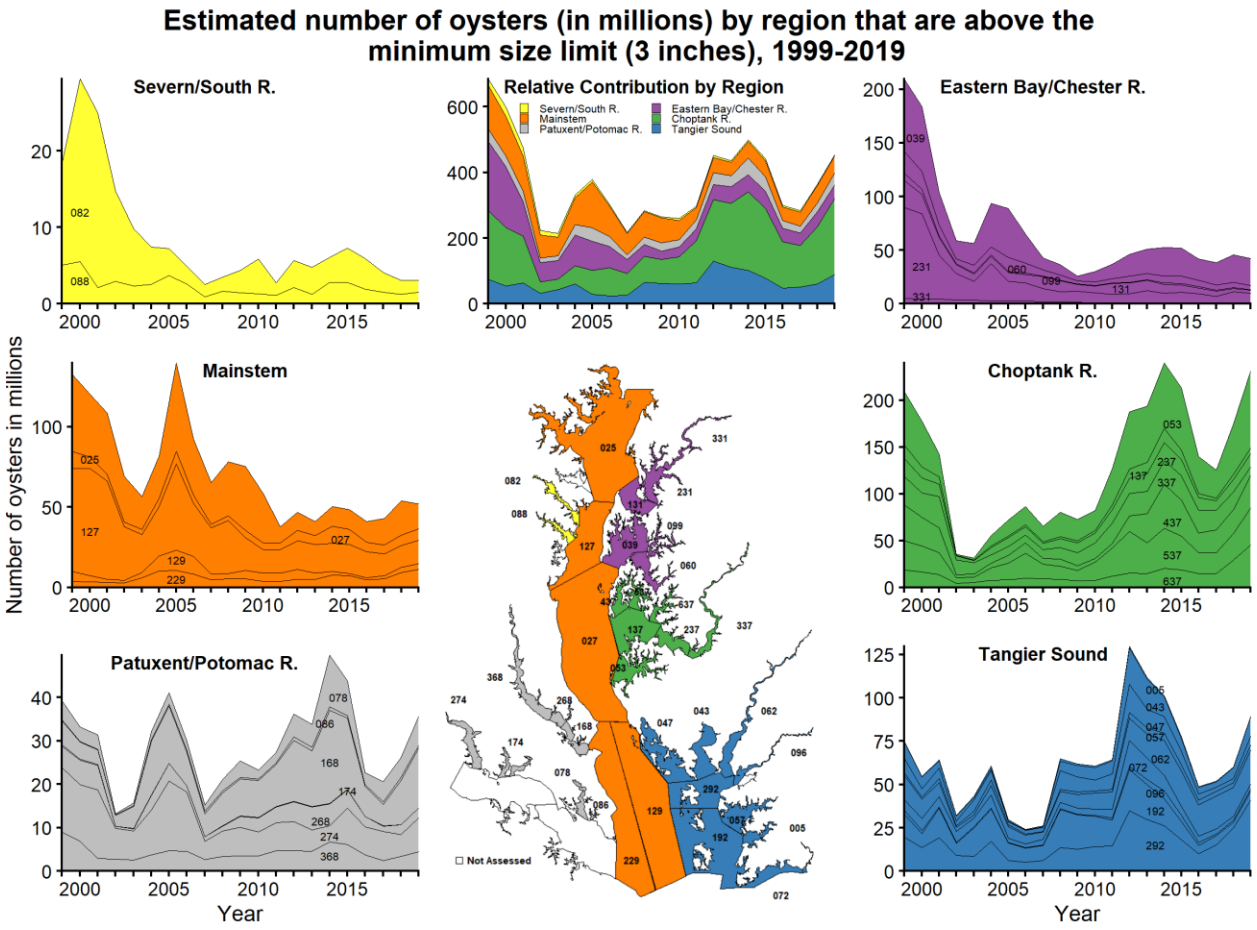

Fig. 1. Estimated number of market size oysters (in millions) by region, during 1999-2019. Trends in abundance are presented by NOAA Code within six regions. The regions are displayed on the map as well as the NOAA Code locations. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

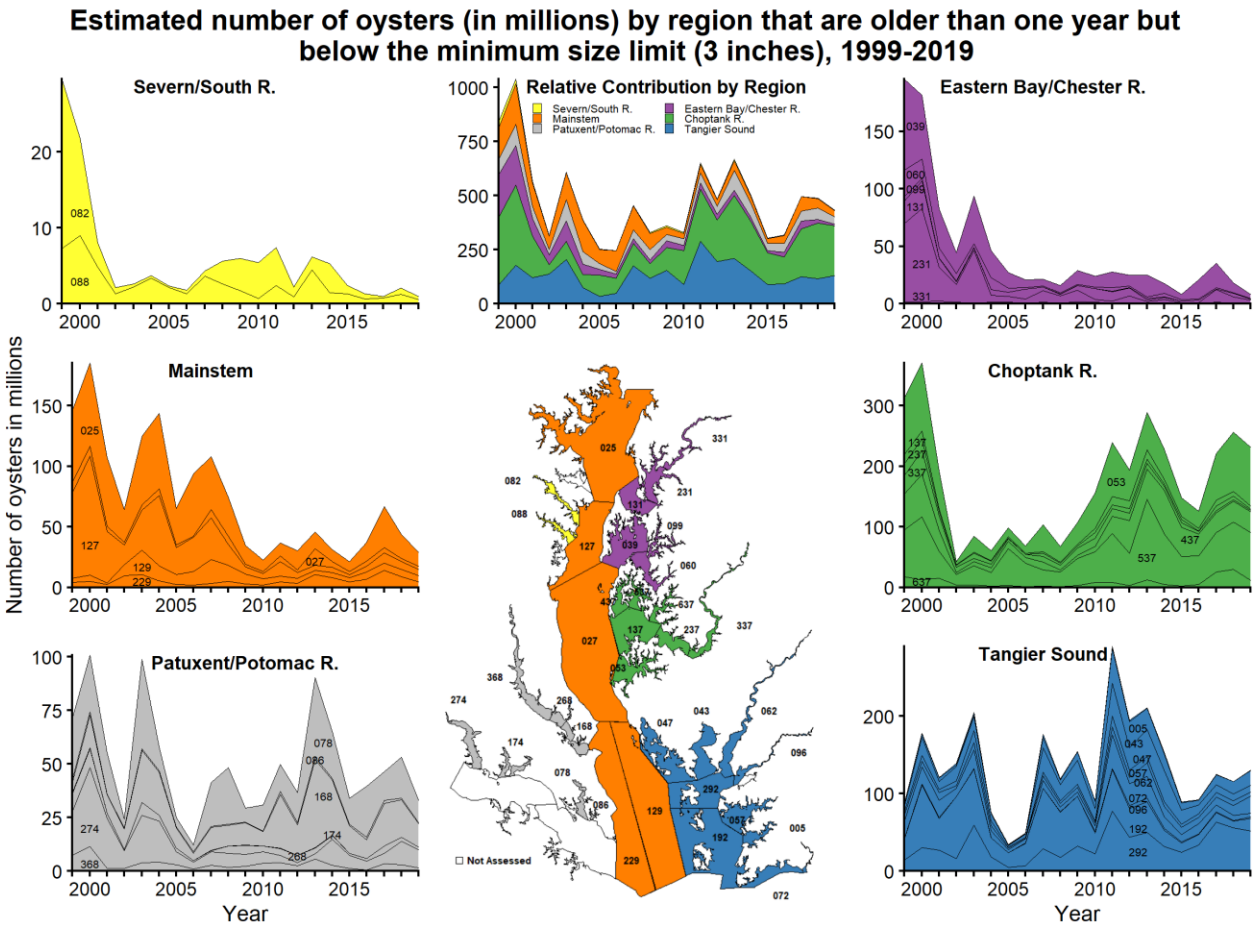

Fig. 2. Estimated number of small oysters (in millions) by region, during 1999-2019. Trends in abundance are presented by NOAA Code within six regions. The regions are displayed on the map as well as the NOAA Code locations. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

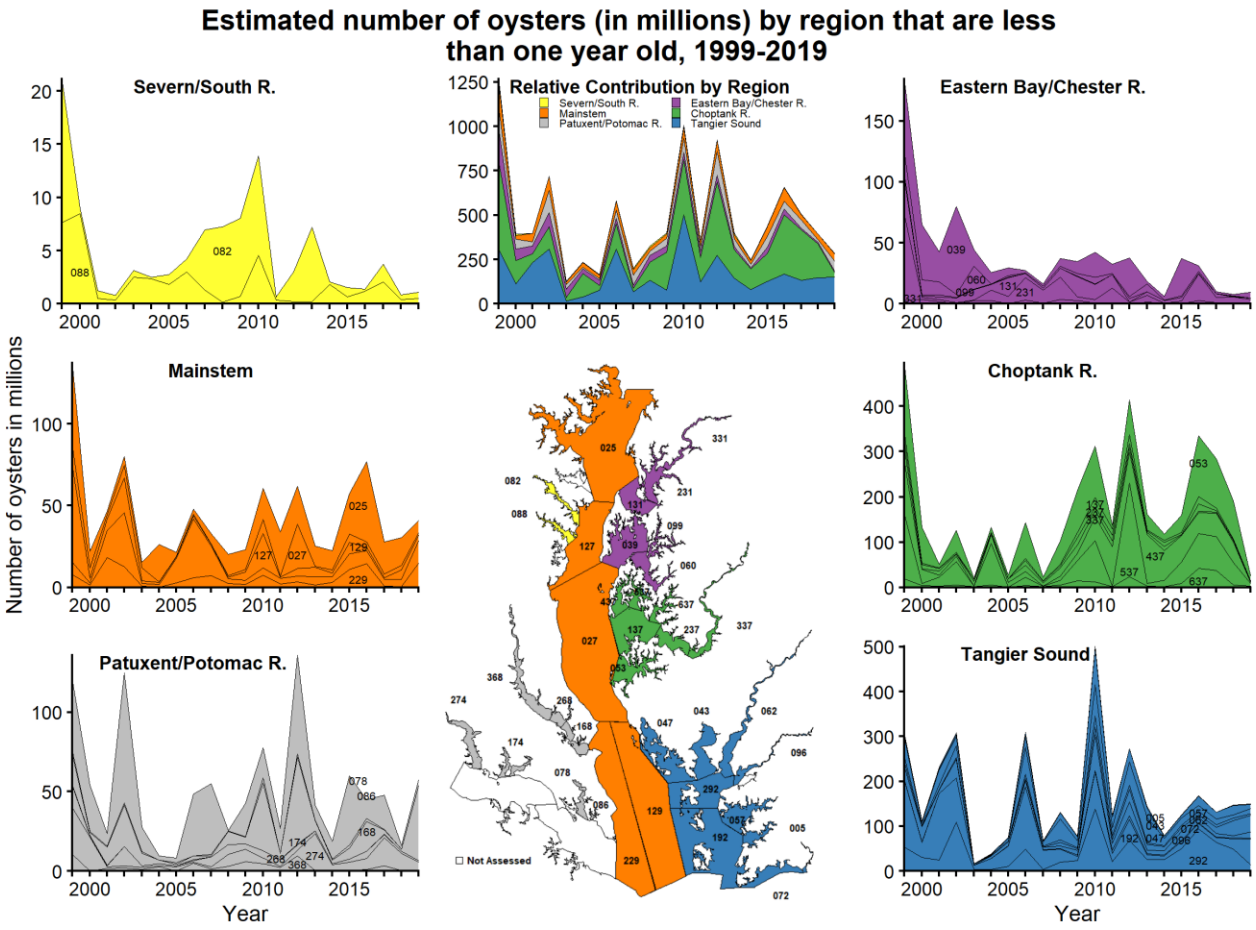

Fig. 3. Estimated number of oyster spat (in millions) by region, during 1999-2019. Trends in abundance are presented by NOAA Code within six regions. The regions are displayed on the map as well as the NOAA Code locations. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

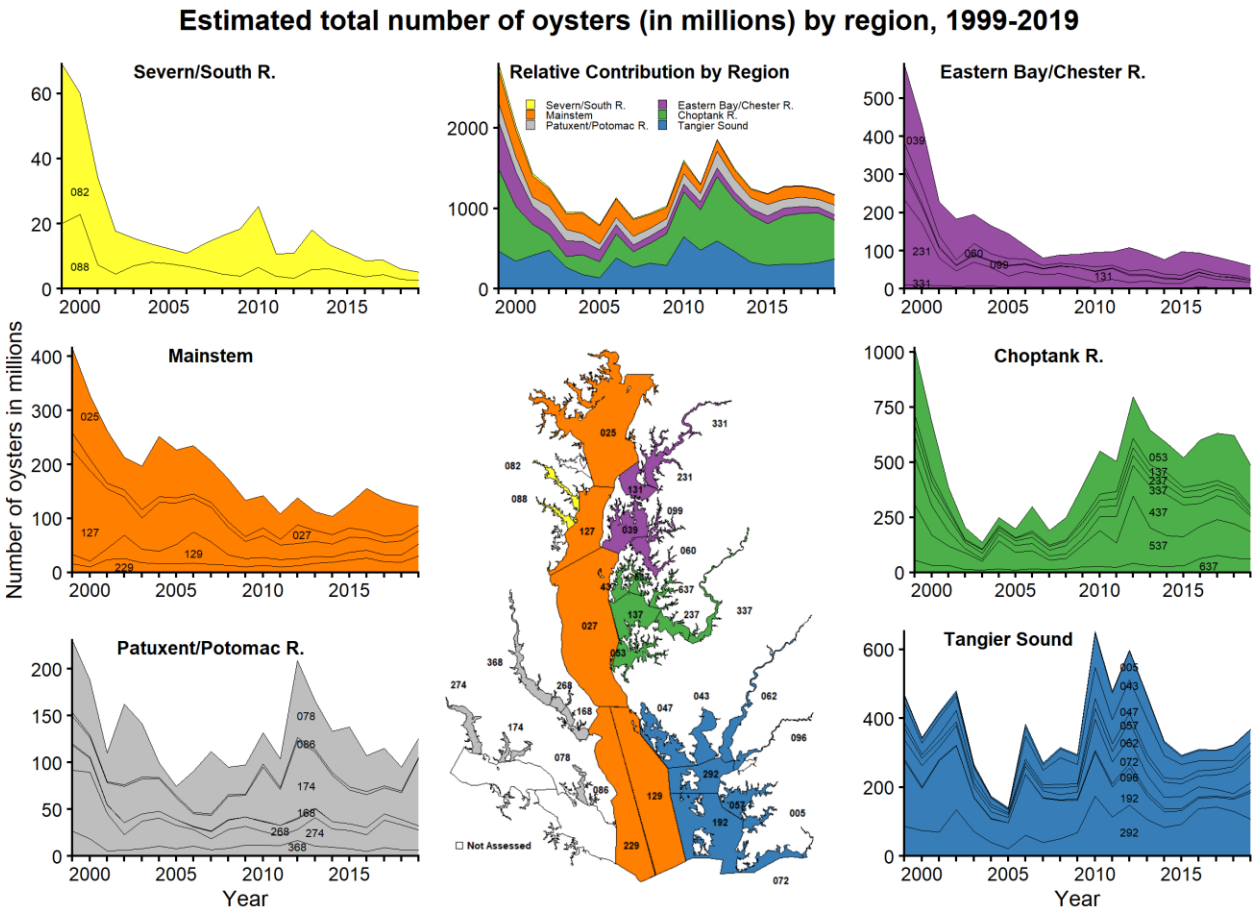

Fig. 4. Estimated total (spat, small, and market) abundance of oysters (in millions) by region, during 1999-2019. Trends in abundance are presented by NOAA Code within six regions. The regions are displayed on the map as well as the NOAA Code locations. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

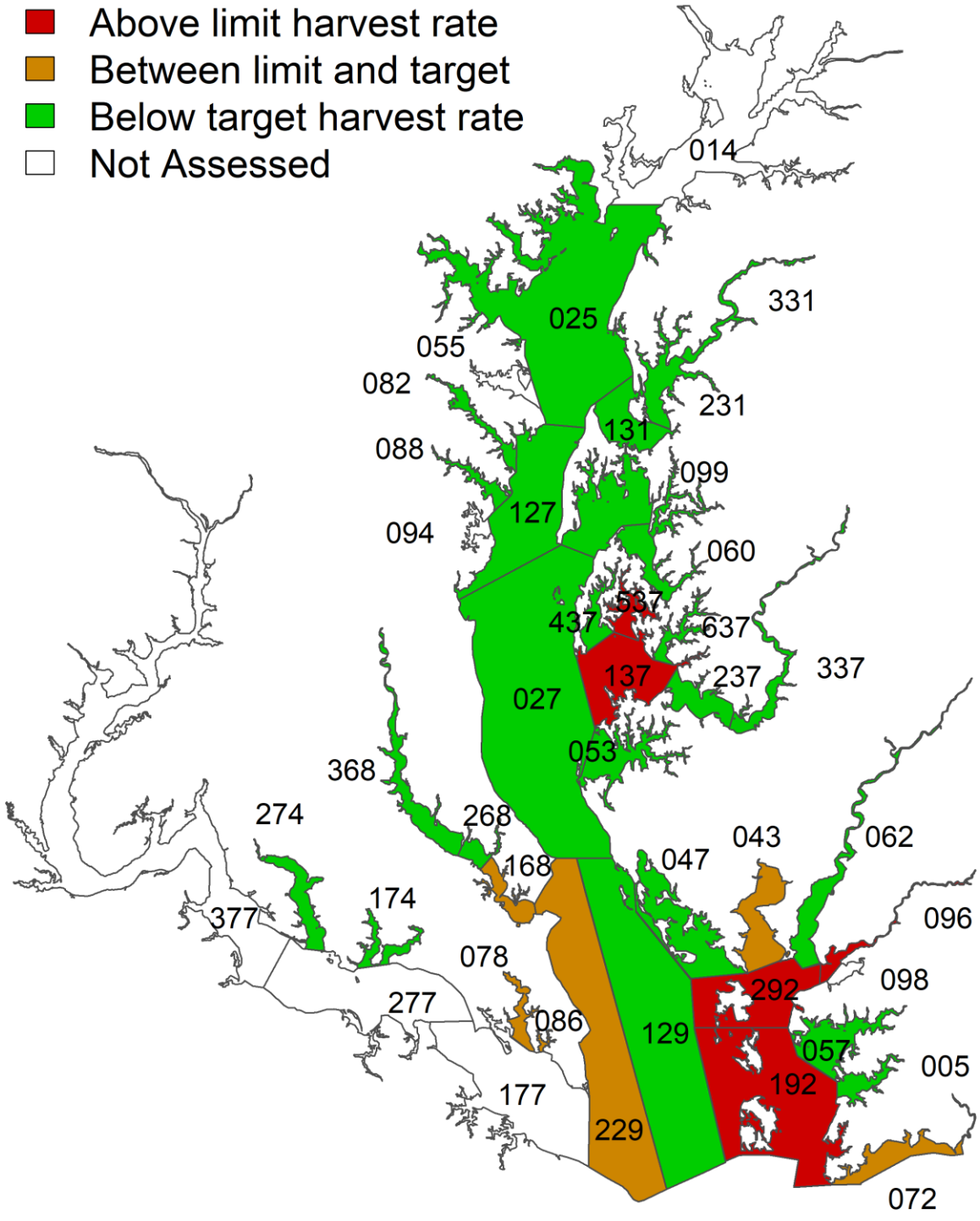

Fig. 5. Estimated harvest fractions compared to target (U_{MSY}) and upper limit (U_{limit}) reference points for the 2019-2020 season by NOAA Code. The estimates of harvest fraction have been adjusted for planted spat.

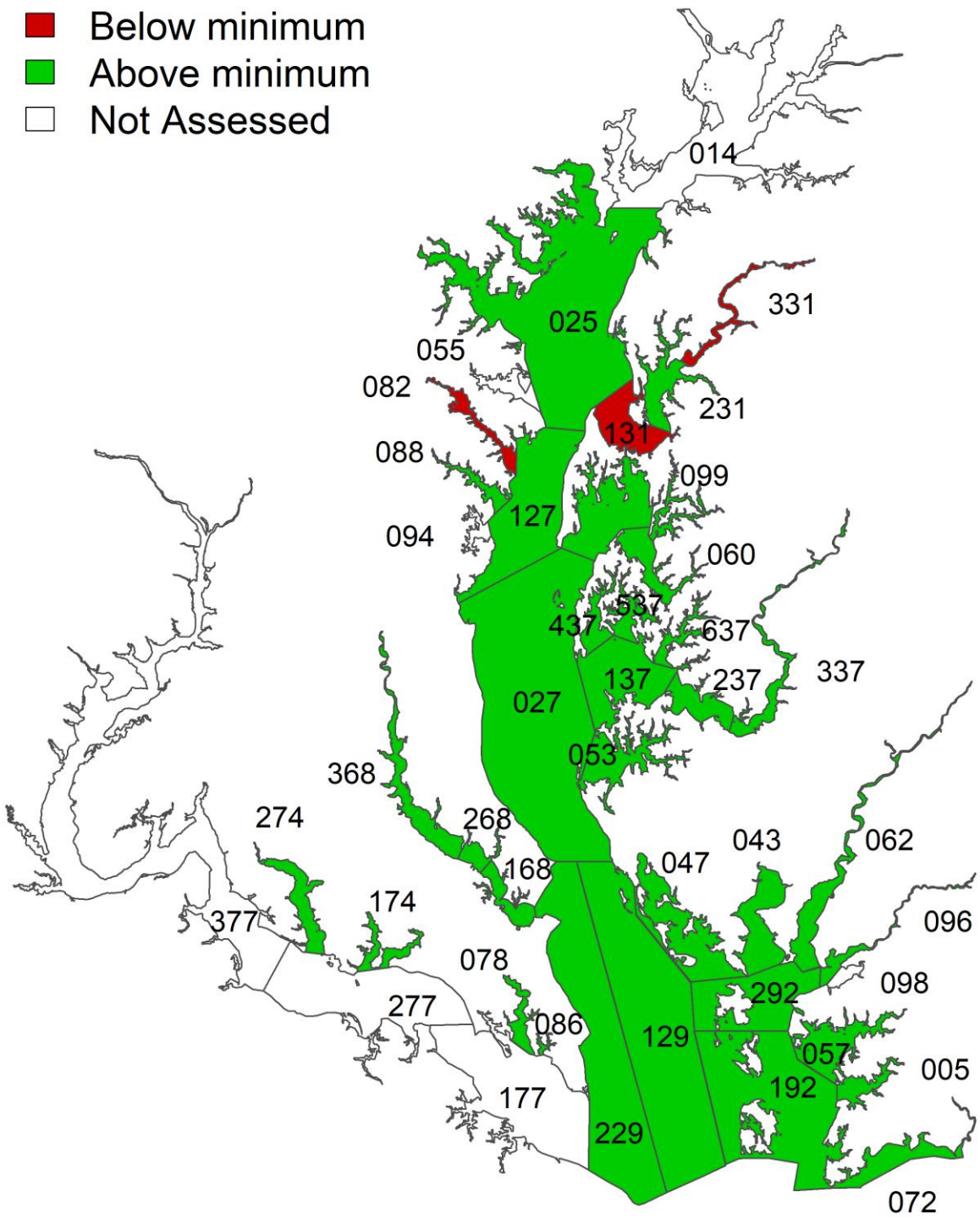

Fig. 6. Status of market oyster abundance in the last year of the assessment (2019-2020 season) relative to the lower limit abundance reference point, which is the lowest estimated abundance during 1999-2017 for each NOAA Code. Note that years indicate the beginning of the fishing season (2017 refers to the 2017-2018 season).